Michigan Odor Print
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OVERVIEW AND BACKGROUND

Michigan Odor Print is a planning tool for assessing potential odor impacts from livestock facilities. The output, called an Odor Print, is a radial plot which represents approximate distances that one must be away from the odor source to detect a noticeable or stronger odor up to 1.5%, 3% and 5% of the time for each of the 16 compass directions. Figure 1 is an example.

Odor Print has been developed on a Microsoft Excel® spreadsheet. The user enters odor emission data and surface area for each of the odor sources on the site. See Figure 2. From this, an odor dispersion model called OFFSET (Odor From Feedlots Setback Estimation Tool) that has been developed and validated at the University of Minnesota is used. It estimates distances that one needs to be down wind until the odors are just noticeable for 6 different wind stability conditions. Weather data have been used to estimate how frequently each of these stability conditions occurs during the months from April to October for each of the 16 compass directions. The frequency data is then used to choose representative wind stability conditions that occur for up to 1.5%, 3% and 5% of the time respectively. The combination of representative wind stability category for each wind direction and the total odor emission factor is entered into OFFSET, which then estimates the distance for each wind direction. These results are graphically displayed in an Odor Print.

Stability conditions are characterized using Pasquill turbulence types which range from F stability which are the most stable and within which odors remain noticeable over a relatively long distance. D stability conditions are less stabile and where more vertical mixing occurs and within which odors remain noticeable over a shorter distance. Stability types are designated as F<3, F<7, E<7, E<12, D<12 and D<18. The letter describes the stability condition and the numbers designates wind speeds in miles per hour. F stability is characterized as being stable; E stability is characterized as being slightly stabile and D stability as being neutral. The F<3 category includes only winds with F stability that have wind speeds less than 3 miles per hour. The F<7 category includes F stability winds with wind speed from 4 to 7 miles per hour AND F stability winds with speeds less than 3 miles per hour. The E<7 category includes E stability winds with speeds less than 7 miles per hour AND all of the F stability conditions which have wind speeds that range from 0 to 7 miles per hour. This pattern continues for the remaining categories. This frequency data is used to choose representative wind stability conditions that occur for up to 1.5%, 3% and 5% of the time respectively.

Initially, hourly data that were available from the EPA Office of Air Quality Planning and Standards in their Support Center for Regulatory Air Models program from 9 weather stations: Grand Rapids, Lansing, Flint, Detroit, South Bend, Muskegon, Alpena and Sault Ste. Marie for the years 1984 to 1992 were used to develop distribution patterns for each weather station. Analysis of the weather date indicated that a characteristic frequency distribution that is similar for all of the weather stations exists for the D and E stability conditions. However for the highly stable F stability conditions, the distributions of are different for each weather station. The F stability distributions are highly inflenced by conditions that are unique to each site. Therefore using date from a nearby weather station may not be representative of that nearby site.

The weather data has been used to develop a representative distribution pattern that can be used for planning purposes. The general approach was to choose a stability class that was most representative of occurring 5%, 3% and 1.5% of the time respectively for each of the 16 wind directions.

The objectives were to:

- maximize the number of times the representative pattern correctly estimates the stability condition that occurs at the given frequency
- minimizes the number of times that the representative pattern under estimates the stability condition that occurs at the given frequency
- Maximize the sum of the correct estimates plus over estimates of the stability condition that occurs at the given frequency.

Another way of saying this is that the objective was to under estimate the distance as infrequently as possible, estimate correctly as often as possible and choose to over estimate the distance rather than underestimate the distance without being overly conservative.

As a result of some preliminary work on a cooperative effort between Michigan State University and Purdue University on a bulletin under development, the distribution for the D and E stability conditions were found to be quite similar to Michigan's. It would appear that the variability of F stability wind distributions is the result of local conditions that are not necessarily related to geographic location at least within Michigan and Indiana. The data for Indiana were included to increase the number of observations and therefore the reliability of the results. The weather stations that were added to the database included Louisville, Kentucky, Evansville, Indianapolis and Fort Wayne in Indiana. South Bend, Indiana had already been included as part of the Michigan data. This resulted in a total of 12 observation.

For the 5% frequency, the pattern that resulted predicted the correct stability condition 66.1% of the time. It chose a more stable stability condition (resulting in an over estimate of distance) 24.5% of the time and chose a less stable conditions (resulting in an under estimate of distance) 9.4% of the time. The over estimates of distance were misses by 1 stability category 98% of the time and misses by 2 stability categories 2% of the time. The under estimates of distance were misses by 1 category 83% of the time and misses by 2 categories 17% of the time. This will result in distances being either estimated correctly or over estimated 90.6% of the time. The 9.4% under estimates of distance means that this type of error will tend to occur for 1 or 2 of the directions at any particular site. These types of errors tended to be randomly distributed among all directions.

The pattern for the 3% frequency predicted the correct stability condition 51% of the time. It chose a more stable stability condition (resulting in an over estimate of distance) 33% of the time and chose a less stable conditions (resulting in an under estimate of distance) 16% of the time. The over estimates of distance were misses by 1 stability category 83% of the time and misses by 2 stability categories 17% of the time. The under estimates of distance were misses by 1 category 60% of the time and misses by 2 or 3 categories 40% of the time. This will result in distances being either estimated correctly or over estimated 84% of the time.

The pattern for the 1.5% frequency predicted the correct stability condition 47% of the time. It chose a more stable stability condition (resulting in an over estimate of distance) 33% of the time and chose a less stable conditions (resulting in an under estimate of distance) 20% of the time. The under estimates of distance were misses by 1 category 64% of the time and misses by 2 or 3 categories 36% of the time. The over estimates of distance were misses by 1 stability category 63% of the time and misses by 2 or 3 stability categories 37% of the time. This will result in distances being either estimated correctly or over estimated 80% of the time. The relatively lower accuracy for the 1.5% frequency reflects the fact that the more highly stable conditions occur at the lowest frequency and are distributed based upon locally site-specific conditions. They therefore have more influence at the lower (3 and 1.5%) frequencies.

One way of interpreting the boundary of the Odor Print is that noticeable or more than noticeable odors are likely to be observed UP TO 5%, 3% or 1.5% of the time respectively. Another way of looking at this is that, areas that are at or beyond the Odor Print will be odor annoyance free AT LEAST 95%, 97% or 98.5% of the time respectively.

Using Odor Print

The spreadsheet has been constructed on Microsoft Excel®. All the data entries are made in rows 3 through 18. See Figure 2. Cells for data entry are designated with green colored lettering. The first entry is made in cell B3 and has the word “NAME” to the left of it in cell A3. This is a space to enter the name of the person making the entries. The cell has been formatted to wrap text until it fills the space provided. The next input cell is B4 and 5. This area can be used to describe the location. This cell has also been formatted to wrap text until the text fills the space.

The table below line 5 is used to list all of the types of animal buildings and manure storages located at the site that are odor sources. Under “Animal Type”, enter a description of the animal type such as Beef, Dairy, Swine, Poultry etc. Under “Building or Manure Storage Type” enter descriptive information about the type of building or manure storage being considered. For each of the rows containing descriptive information, enter into column E the surface area of the building or manure storage in square feet. Enter the estimated odor emission number for each row into column F.

This information can be obtained by scrolling to the right to the colored charts (Figure 3) that have odor emission numbers for a variety of animal types and building and manure storage types. Column G is used to enter any adjustment factors that may be appropriate for various odor control technologies as shown in the table labeled “Odor Control Technology Adjustment Factors” that can be seen by scrolling to the right and down (Figure 3). If there is no odor control adjustment leave a 1.0 in that cell. The spreadsheet then calculates the “Odor Emission Factor” for each of the components and the “Total Odor Emission Factor”, in row 19, for all of the components listed.

The spreadsheet generates two Odor Prints that can be seen by scrolling downward. The first shows the Odor Print for 1.5%, 3% and 5% frequencies. The second, seen by scrolling down, shows the Odor Print for only the 5% frequency.

To print the results, either press the print icon on the control panel or go to “File” then click on “print” then “OK”. This will produce a three-page output (Figure 4 – 3 pages). The first page will contain the input data. The second page will show a full Odor Print showing the outline for 1.5%, 3% and 5% frequencies. The third page will have an Odor Print showing the outline for only the 5% frequency. To the right of each Odor Print graph is a listing of the 6 stability classes with the predicted distance in miles and in feet that correspond to the distances depicted on the Odor Print graph.

Using Odor Print to Assess Odor Impacts

In order to get a visual image of the impact region, a scale drawing of the livestock facility and the surrounding area that includes a radius at least equal to the longest distance indicated on the Odor Print graph as measured from the extreme ends of the facility. The next step is to either enlarge or reduce the size of the Odor Print graphs so that the distances are the same scale as the drawing of the livestock facility and vicinity. Make a copy of the correctly scaled Odor Print graph on overhead transparency film. This image can then be laid on top of the facility drawing so that both images can be seen together.

To understand how to plot the impact distances it is useful to have a little background on how the odor emissions data were collected and how the OFFSET model was validated. Air was sampled from the discharge of ventilating fans, from the downwind side of naturally ventilated buildings and from a covered hood floating on the surface of liquid manure storages. Air flow rates were estimated using the ventilation rates for the fans being sampled, by measuring carbon dioxide concentrations in the air from naturally ventilated air to infer a ventilation rate and from the air flow rate of the fan on the sampling device within the floating hood for the manure storages. The air samples were analyzed for odor intensity. The plan-view surface area of the building or manure storage was measured. The combination of odor intensity, ventilation rates and surface area allowed calculation of an odor emission number. This value was used as input into the odor dispersion model. To validate this model, trained observers were used to determine the location where the odor could be noticed at a level where a casual observer would notice an odor if they were prompted to notice an odor. That is an odor that is somewhat more intense than just detectable. These distances were measured from the downwind side of the building or manure storage being validated. At this same time air samples collected and ventilation rates were measured. The model results were compared to the actual measured distance.

The validation was done on the basis of individual odor producing components located on actual farms. By adding the emissions from all of the components within a farmstead system, Odor Print is used to estimate the impact of a farmstead system. To be most consistent with how the data were collected, plot the distance from the downwind side of the most downwind odor-producing component in the farmstead system for each of the 16 wind directions.

For farmstead systems that are long and narrow and where neighbors are located within 2.5 times the length of the long axis of the farmstead and in a direction that is generally perpendicular to the long axis of the farmstead the neighbor will be impacted by different parts of the farmstead depending upon wind direction. An approach in this case is to look at the situation from the point of view of the neighbor. The system is depicted in Figure 5. In this situation, odor-carrying winds that may reach the neighbor move toward the NNE, North and the NNW. When the wind is blowing toward any one of these directions, odors will most likely come from only part of the farmstead. When the wind is moving toward the NNE, the odors are coming from western manure storage. When the wind is moving toward the north, the odors will be coming from the freestall building. When the wind is moving toward the NNW, odors will be coming from the eastern manure storage. The approach would be to calculate an odor emission number for all the odor producing components in each sector and generate an Odor Print for each sector (Figure 6 and 7 – 3 pages each). Measure the distance from the midpoint of the downwind side of the farmstead sector to the residence. Using the chart with all three frequencies, estimate the frequency of occurrence using the distance from the map. In this example, when the wind is moving toward the NNW odors will be coming from the eastern manure storage. Using the odor print for the manure storage (Figure 6) and looking for the 1500 feet distance on the full odor print we see that this corresponds approximately to the E<7 distance. Looking at the full odor print the E<7 distance occurs between the 1.5 and 3% odor print. Let's use 2%. When the wind is moving toward the north, odors will be coming from the freestall barn. Using the freestall barn odor print we again find that the 1500 feet corresponds to the E<7 distance. This occurs between the 3% odor print and the 5% odor print. Let's use 4%. When the wind is moving toward the NNE odors will be coming from the western manure storage. The E<7 occurs directly on the 1.5% odor print. If we total the all the frequencies (2 + 4 + 1.5) we get 7.5%. If we use the total system emission number we find that the 1500 feet falls inside the 5% odor print (Figure 8). This suggests that odors will occur more frequently than 5% of the time.

Odor Print can also be used to assess odor impacts at a particular neighbor site from neighboring farmsteads. The total impact for that site will be the sum of the impacts from each farmstead.

Some Perspective

The foundational date that drives this model is the odor emissions data. This data is derived from actual measurements in the field from actual operating facilities. To provide a sound basis for guidance, the emission values used in the model have been chosen, on the basis of data that is available, as being the most representative for the type of facility described. It is the most extensive odor emissions database currently available. This kind of data is characteristically variable. Fluctuations of + or – 50% around the selected representative value are commonly encountered. A 50% fluctuation in emissions results in approximately a 40% fluctuation in impact distance.

The criteria used to choose the stability class that is most representative for the Odor Print is somewhat conservative in the sense that there is a preference for over estimates of impact distance than for under estimates of distance. This means that it is somewhat over protective of neighbors. Yet, in the case of the 5% frequency, there is a 9% chance that the distance will be under estimated on the order of 40% of the estimated value. For the 5% frequency, perhaps a useful way of thinking about the boundary line on the Odor Print is to think of it as a thick gray line that 40% longer and 30% shorter than the boundary line. The longer distances will have a 9% (1 or 2 in 16 directions) probability of occurring and the shorter distance will have a 24% (4 in 16 directions) probability of occurring.

Planning Issues

Sample calculations using currently common types of facilities indicates that odor impacts will frequently extend beyond the property line set back distances described in the Generally Accepted Agricultural Management Practices (GAAMPS) for Site selection and Odor Control for New or Expanding Livestock Operations document for the right to farm act. These impact distances for the “up to 5%” frequency Odor Prints are often 3 to 5 times longer than the property line set back distances. The judgment of the committee that developed the Odor GAAMPS was that odors that occur 5% of the time or more have a material probability of being be annoying and may not be readily tolerated.

One of the factors that influence this choice of response is how often the odor is noticed. There is a 91% chance that there will be no noticeable odor at that location for at least 95% of the time. There is a 9% chance that there will be no noticeable odors for less than 95% of the time. These people will experience odors up to around 5% of the time between April and October. These will tend to occur at night, given that the more stabile conditions that carry odors longer distances tend to occur at night. For people with above normal odor perception capacity, odor annoyance-free frequencies will be lower.

It is more complex than this though. People planning the new or expanding livestock operation faced with making a judgment call. The fundamental question is how can we coexist as fellow inhabitants of this locality? Within this context there are questions:

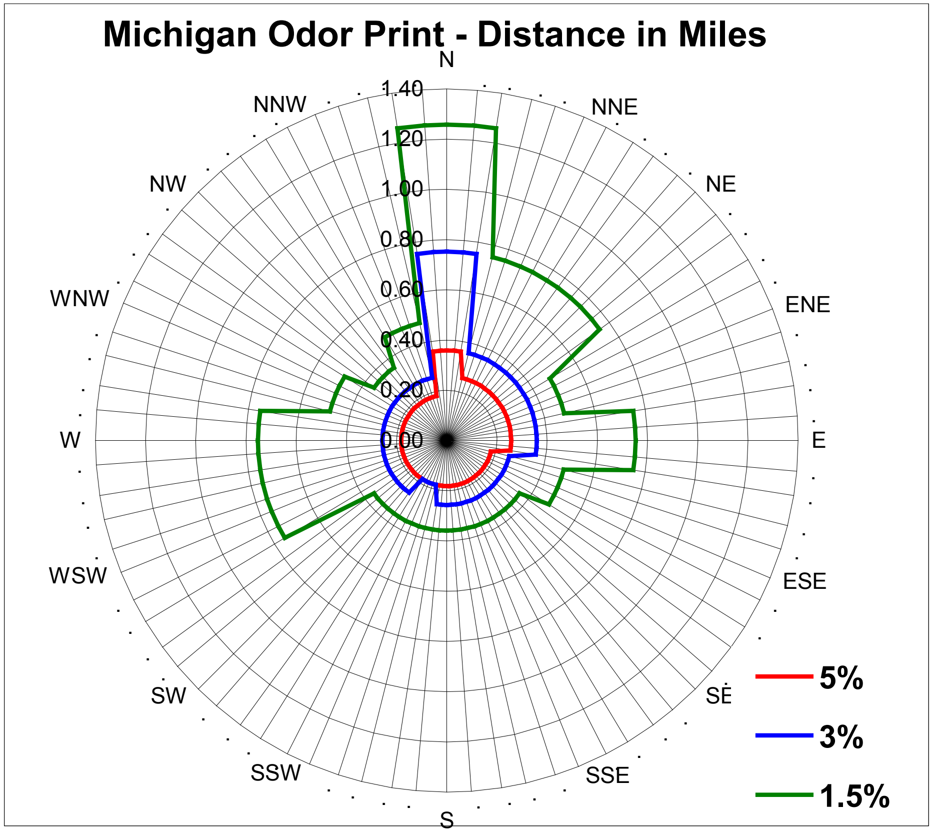
1. What is the perceived and intended nature of your relationship with your neighbors and the environment?

2. How is this intended nature being communicated to your neighbors – both consciously and unconsciously?
3. How and to what extent should this be a local community decision?

Figure 1. Example Odor Print.

Site: **Example**

Total Odor Emission Factor = 100



Stability Class		Distance Miles	Distance Feet
F<3	=	1.26	6,640
F<7	=	0.75	3,971
E<7	=	0.48	2,535
E<12	=	0.36	1,889
D<12	=	0.26	1,355
D<18	=	0.18	957

The distances represented on this odor print are approximate distances that one must be away from the odor source to detect a noticable odor or stronger up to 1,5%, 3% and 5% of the time for each of the 16 wind directions.

Figure 2. Example data entry and odor emission factor calculation sheet.

	A	B	C	D	E	F	G	H
1						Version: Sept. 7, 2001		
2	**Odor Print for the Michigan**							
3	**Prepared by:**	**Howard Person**						
4	**Site:**	**Example**						
5								
6–8	**Animal Type**	**Building or Manure Storage Type**			**Area Sq. Ft.**	**Odor Emission Number**	**Odor Control Factor**	**Odor Emission Factor**
9	**Animal**	**Building A**			**59000**	**6**	**1.0**	**35.4**
10	**Animal**	**Manure Storage A**			**50000**	**13**	**1.0**	**65.0**
11							**1.0**	**0.0**
12							**1.0**	**0.0**
13							**1.0**	**0.0**
14							**1.0**	**0.0**
15							**1.0**	**0.0**
16							**1.0**	**0.0**
17							**1.0**	**0.0**
18							**1.0**	**0.0**
19		**Total Odor Emission Factor =**						**100.4**

Odor Emissions Numbers for Animal Housing With an Average Management Level			
Species	**Animal Type**	**Housing Type**	**Odor Emission Number (Rate)**
Cattle	Beef/Dairy	Dirt/Concrete lot	4
	Dairy	Free Stall, Scrape or Deep Pit Loose Housing	6
		Tie Stall, Scrape	2
Swine	Gestation	Deep Pit, Natural or Mech. Vent.	50
		Pull Plug, Natural or Mech. Vent.	30
	Farrowing	Pull Plug, Natural or Mech. Vent.	14
	Nursery	Deep Pit or Pull Plug, Natural or Mechanical Vent.	42
	Finishing	Deep Pit, Natural or Mech. Vent.	34
		Pull Plug, Natural or Mech. Vent.	20
		Hoop Barn, Deep Bedded , Scrape	4
		Cargill (Open Front), Scrape; Loose Housing, Scrape; Open Concrete Lot, Scrape	11
Poultry	Broiler	Litter	1
	Turkey	Litter	2

Odor Emission Numbers for Liquid or Solid Manure Storages	
Storage Type	**Odor Emission Number (Rate)**
Earthen Basin, Single or Multiple Cells	13
Steel or Concrete Tank, Above or Below Ground	28
Crusted Solid Manure Stockpile	2

Odor Control Technology Adjustment Factors		
Odor Control Technology		**Odor Control Factor**
Biofilter on All Exhaust Fans		0.1
Geotextile Cover (>=2.4mm or 1 inch)		0.5
Straw or Natural Crust on Manure	2" Thick	0.5
	4" Thick	0.4
	6" Thick	0.3
	8" Thick	0.2
Impermeable Cover		0.1
Oil Sprinkling Inside Swine Barns		0.5

Figure 3. Odor Emission Numbers and Adjustment Factors.

Figure 4. Example Odor Print Output – INPUT SHEET AND ODOR EMISSION FACTOR CALCULATION.

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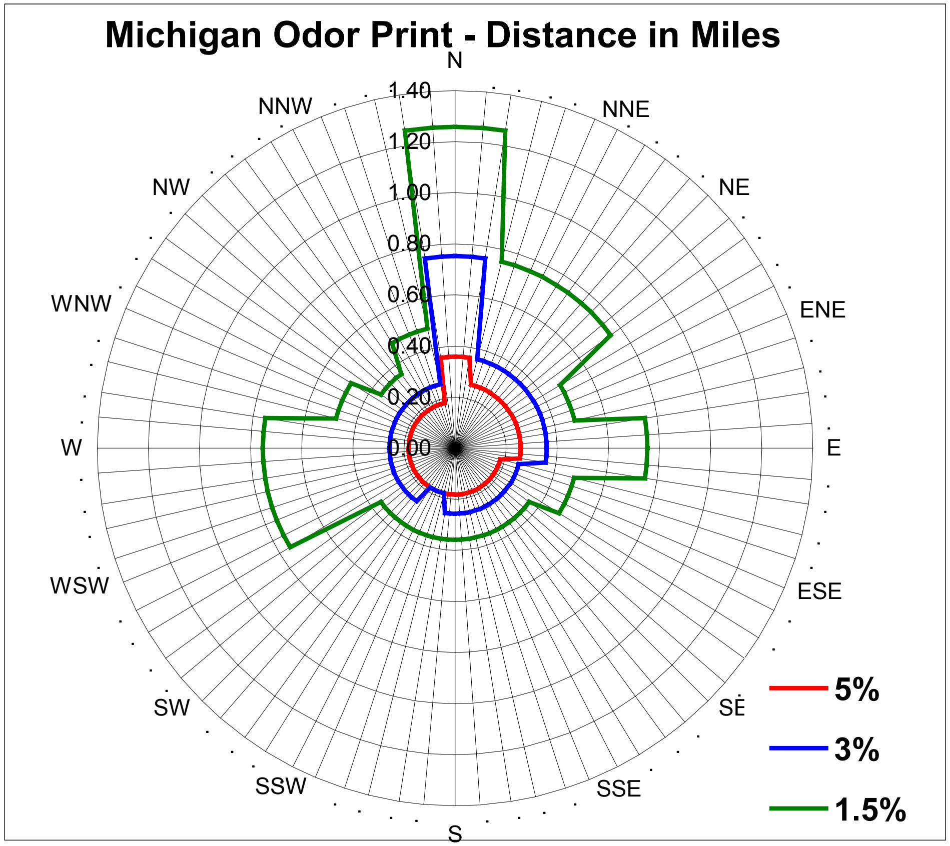
Odor Print for the Michigan

Prepared by:	Howard Person				
Site:	Example				
Animal Type	Building or Manure Storage Type	Area Sq. Ft.	Odor Emission Number	Odor Control Factor	Odor Emission Factor
Animal	Building A	59000	6	1.0	35.4
Animal	Manure Storage A	50000	13	1.0	65.0
				1.0	0.0
				1.0	0.0
				1.0	0.0
				1.0	0.0
				1.0	0.0
				1.0	0.0
				1.0	0.0
				1.0	0.0
	Total Odor Emission Factor =				**100.4**

Figure 4. Example Odor Print Output – FULL ODOR PRINT

Site: **Example**

Total Odor Emission Factor = 100



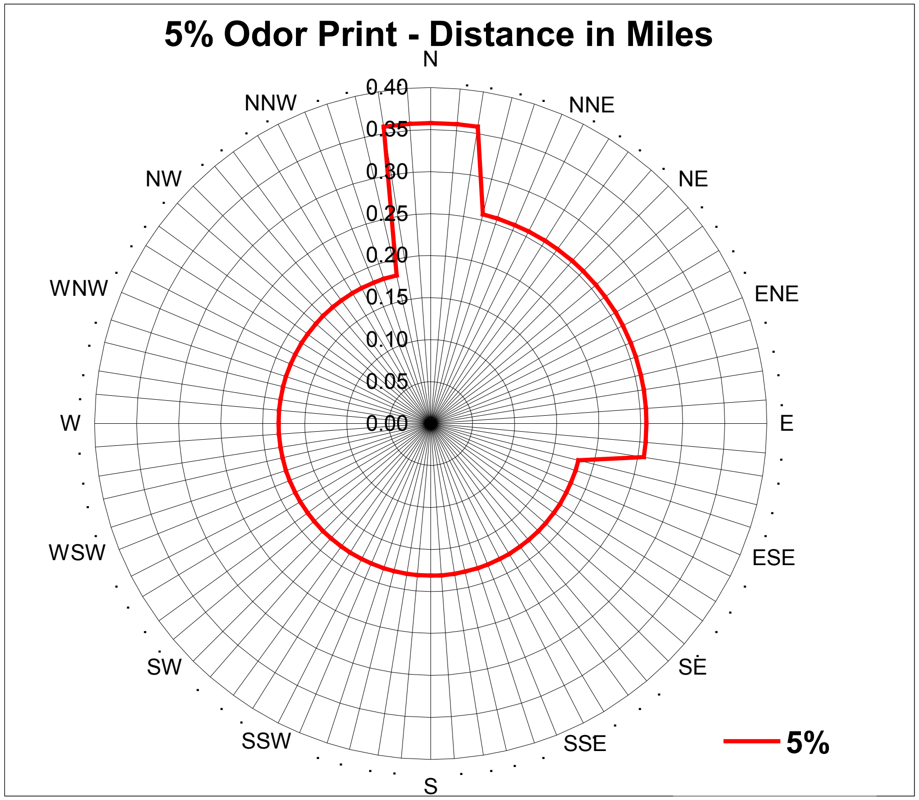
Stability Class		Distance Miles	Feet
F<3	=	1.26	6,640
F<7	=	0.75	3,971
E<7	=	0.48	2,535
E<12	=	0.36	1,889
D<12	=	0.26	1,355
D<18	=	0.18	957

The distances represented on this odor print are approximate distances that one must be away from the odor source to detect a noticable odor or stronger up to 1,5%, 3% and 5% of the time for each of the 16 wind directions.

Figure 4. Example Odor Print Output – 5% ODOR PRINT

Site: Example

Total Odor Emission Factor = 100



Stability Class		Distance Miles	Feet
F<3	=	1.26	6,640
F<7	=	0.75	3,971
E<7	=	0.48	2,535
E<12	=	0.36	1,889
D<12	=	0.26	1,355
D<18	=	0.18	957

The distances represented on this odor print are approximate distances that one must be away from the odor source to detect a noticable odor or stronger up to 5% of the time for each of the 16 wind directions.

Figure 5. Long-Narrow Facility Example.

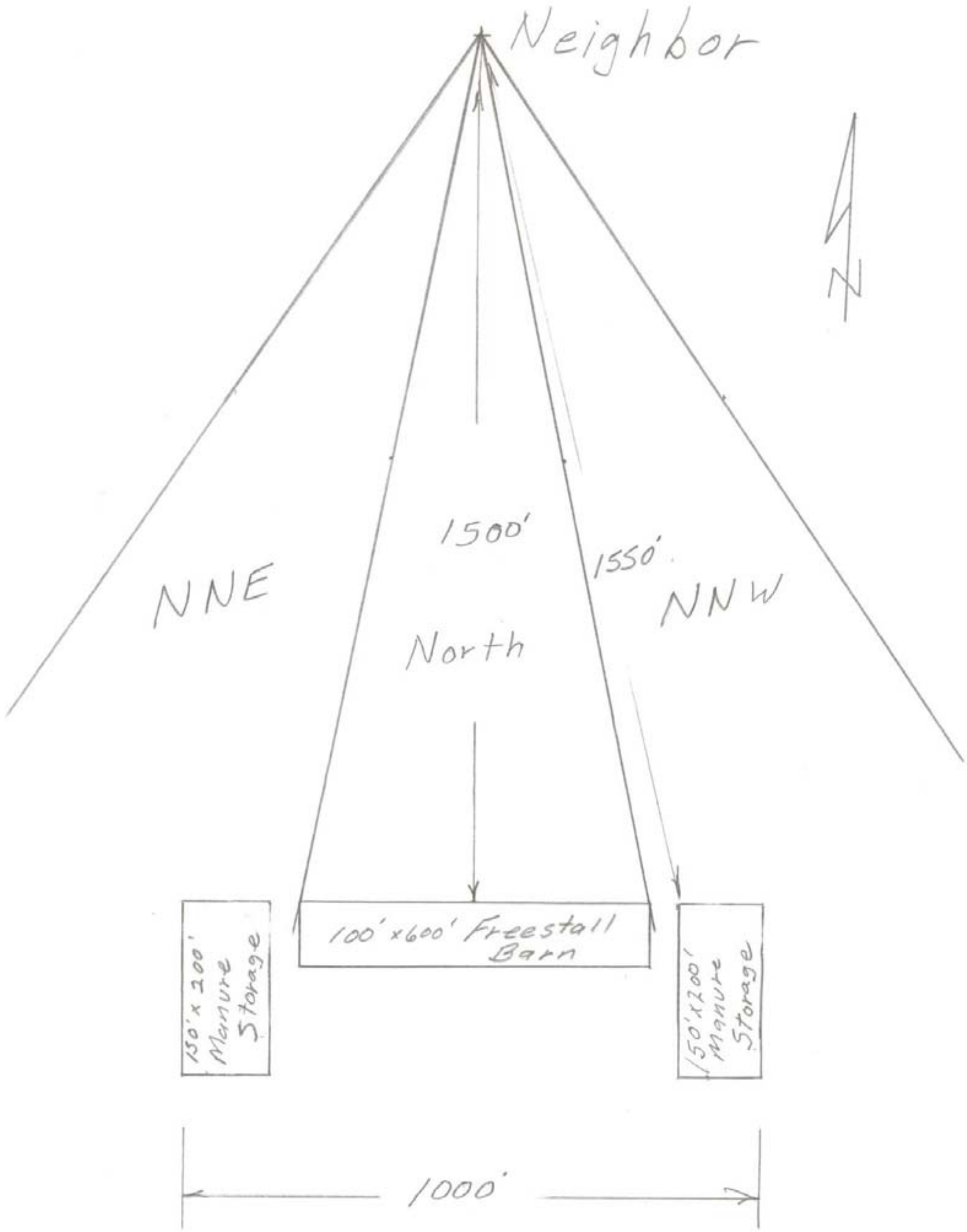


Figure 6. Example for a long-narrow facility including only the east or west manure storage – INPUT TABLE

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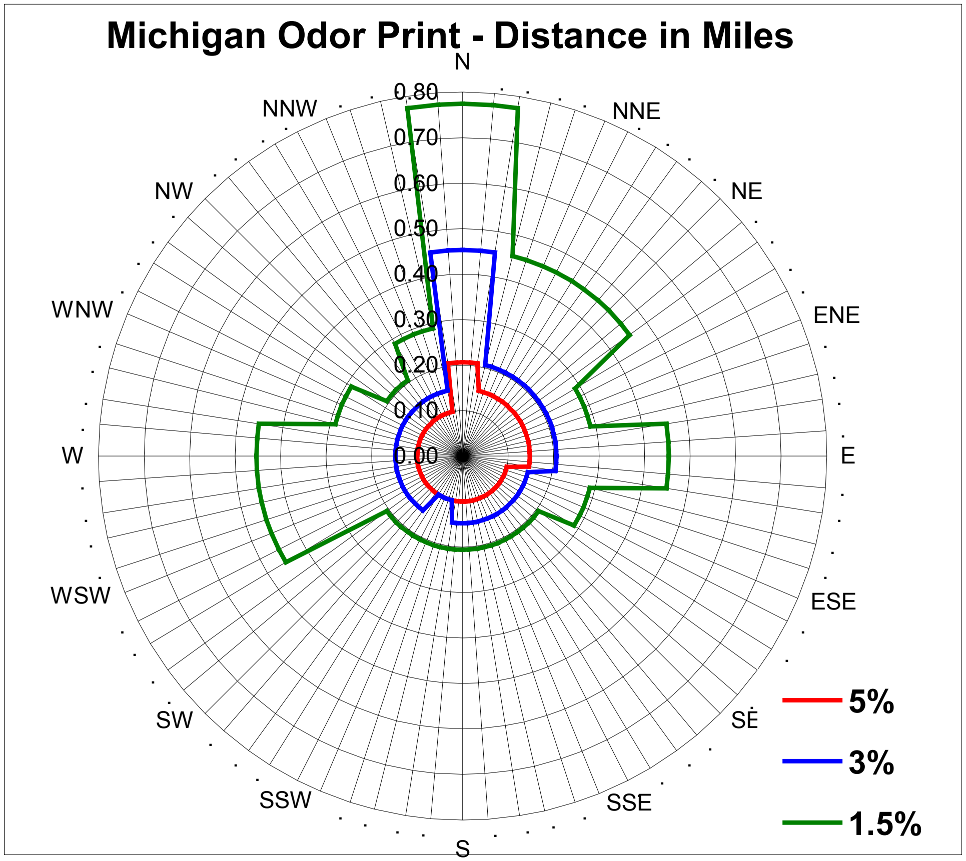
Odor Print for the Michigan

Prepared by:	Howard Person				
Site:	Long-Narrow Example Manure Storages				
Animal Type	**Building or Manure Storage Type**	**Area Sq. Ft.**	**Odor Emission Number**	**Odor Control Factor**	**Odor Emission Factor**
Dairy	E or W Manure Storage	30000	13	1.0	39.0
				1.0	0.0
				1.0	0.0
				1.0	0.0
				1.0	0.0
				1.0	0.0
				1.0	0.0
				1.0	0.0
				1.0	0.0
				1.0	0.0
	Total Odor Emission Factor =				**39.0**

Figure 6. Example for a long-narrow facility including only the east or west manure storage – FULL ODOR PRINT PAGE

Site: **Long-Narrow Example Manure Storages**

Total Odor Emission Factor = 39



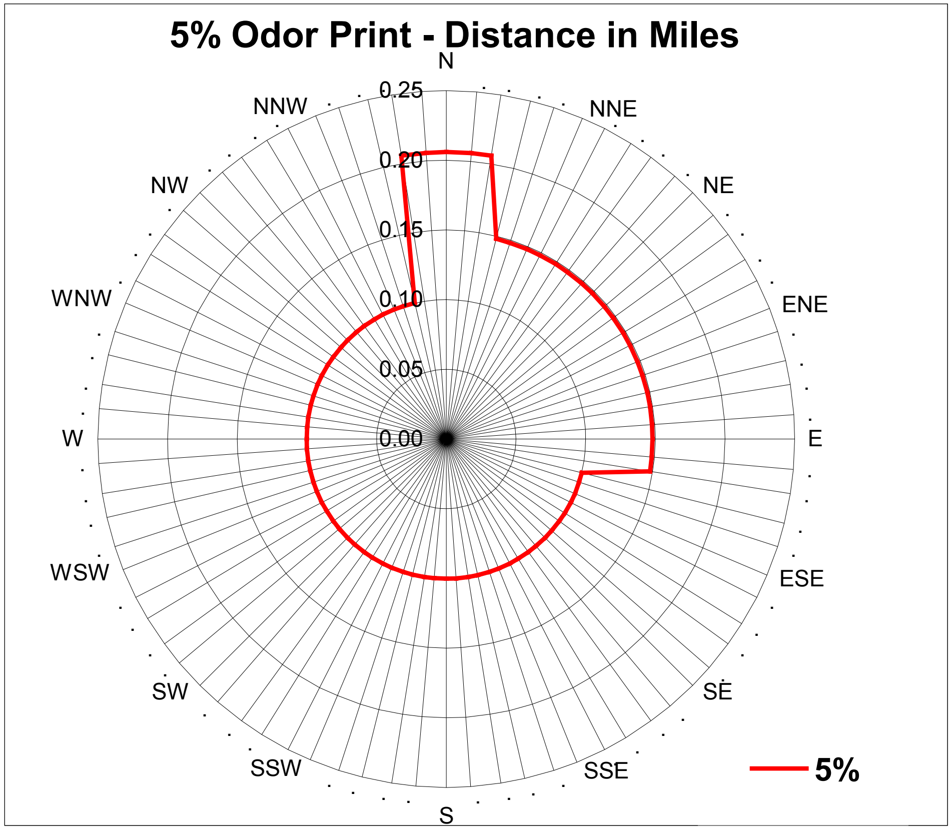
Stability Class	Distance Miles	Distance Feet
F<3 =	0.77	4,087
F<7 =	0.45	2,390
E<7 =	0.29	1,522
E<12 =	0.21	1,087
D<12 =	0.15	781
D<18 =	0.10	529

The distances represented on this odor print are approximate distances that one must be away from the odor source to detect a noticable odor or stronger up to 1,5%, 3% and 5% of the time for each of the 16 wind directions.

Figure 6. Example for a long-narrow facility including only the east or west manure storage – 5% ODOR PRINT PAGE

Site: **Long-Narrow Example Manure Storages**

Total Odor Emission Factor = 39



Stability Class		Distance Miles	Distance Feet
F<3	=	0.77	4,087
F<7	=	0.45	2,390
E<7	=	0.29	1,522
E<12	=	0.21	1,087
D<12	=	0.15	781
D<18	=	0.10	529

The distances represented on this odor print are approximate distances that one must be away from the odor source to detect a noticable odor or stronger up to 5% of the time for each of the 16 wind directions.

Figure 7. Example for a long-narrow facility including only the freestall barn – INPUT PAGE

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Odor Print for the Michigan

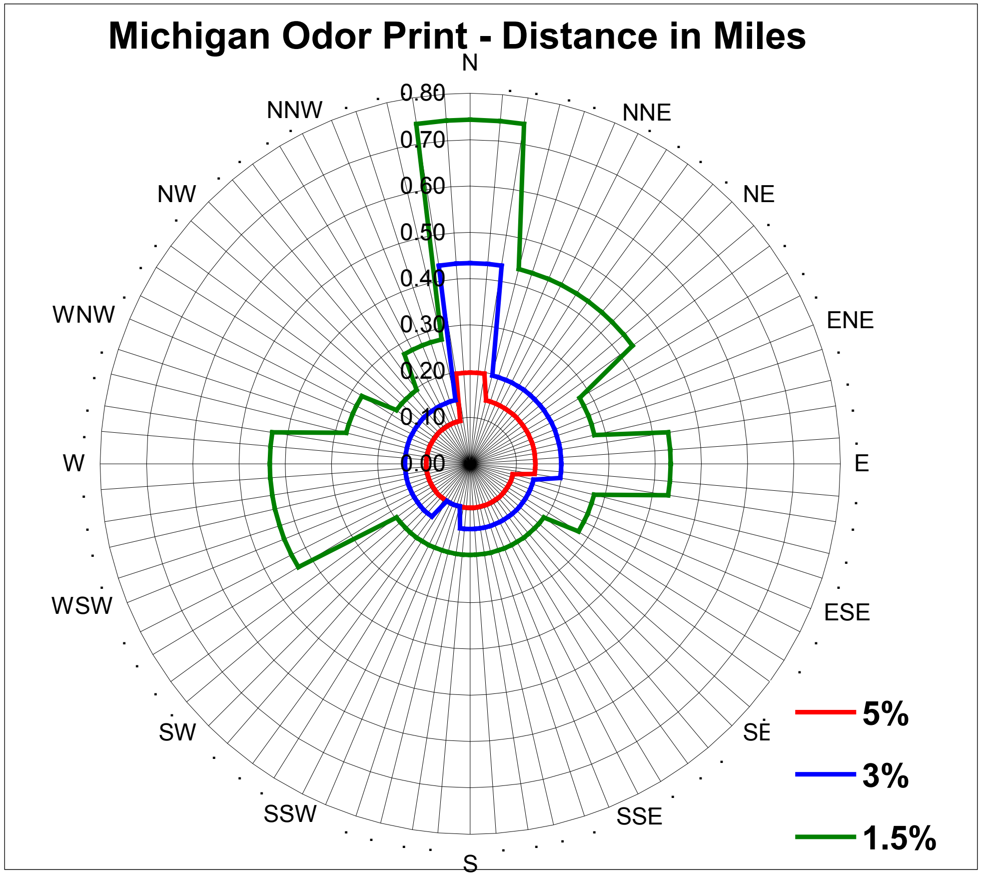
Prepared by:	Howard Person
Site:	Long-Narrow Example Freestall Barn

Animal Type	Building or Manure Storage Type	Area Sq. Ft.	Odor Emission Number	Odor Control Factor	Odor Emission Factor
Dairy	Freestall Barn	60000	6	1.0	36.0
				1.0	0.0
				1.0	0.0
				1.0	0.0
				1.0	0.0
				1.0	0.0
				1.0	0.0
				1.0	0.0
				1.0	0.0
				1.0	0.0
	Total Odor Emission Factor =				**36.0**

Figure 7. Example for a long-narrow facility including only the freestall barn – FULL ODOR PRINT PAGE.

Site: **Long-Narrow Example Freestall Barn**

Total Odor Emission Factor = 36



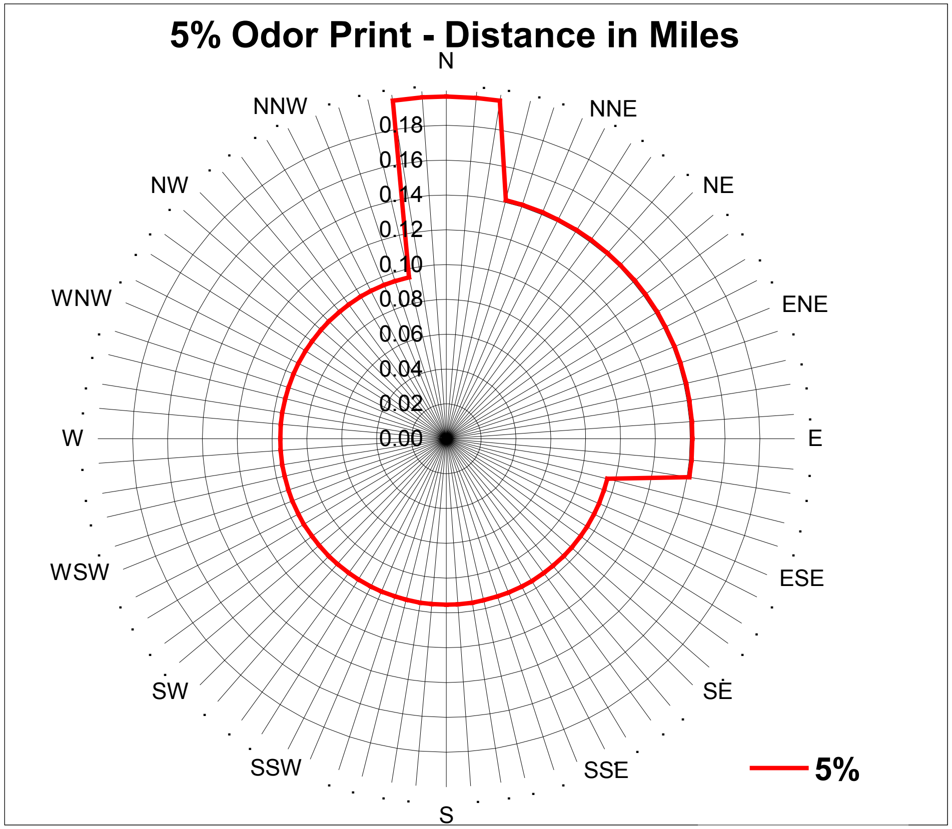
Stability Class		Distance Miles	Distance Feet
F<3	=	0.74	3,923
F<7	=	0.43	2,290
E<7	=	0.28	1,457
E<12	=	0.20	1,037
D<12	=	0.14	746
D<18	=	0.10	503

The distances represented on this odor print are approximate distances that one must be away from the odor source to detect a noticable odor or stronger up to 1,5%, 3% and 5% of the time for each of the 16 wind directions.

Figure 7. Example for a long-narrow facility including only the freestall barn – 5% ODOR PRINT PAGE.

Site: Long-Narrow Example Freestall Barn

Total Odor Emission Factor = 36



Stability Class	Distance Miles	Distance Feet
F<3 =	0.74	3,923
F<7 =	0.43	2,290
E<7 =	0.28	1,457
E<12 =	0.20	1,037
D<12 =	0.14	746
D<18 =	0.10	503

The distances represented on this odor print are approximate distances that one must be away from the odor source to detect a noticable odor or stronger up to 5% of the time for each of the 16 wind directions.

Figure 8. Example for a long-narrow facility including the entire system – INPUT PAGE.

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Odor Print for the Michigan

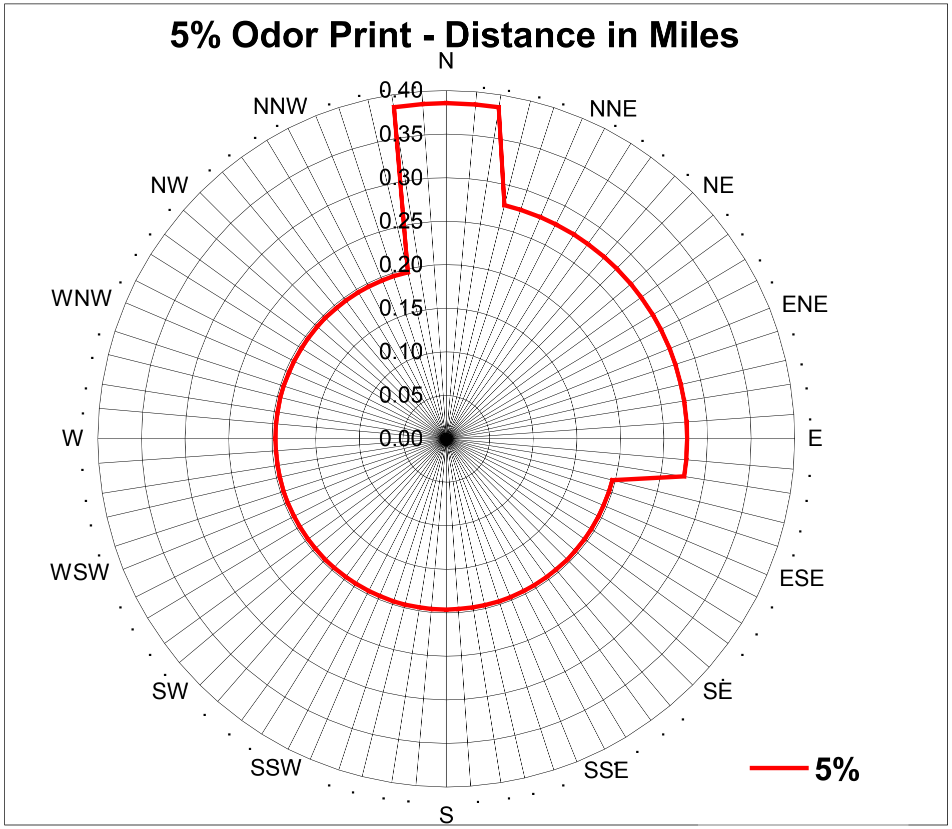
Prepared by:	Howard Person
Site:	Long-Narrow Example Entire System

Animal Type	Building or Manure Storage Type	Area Sq. Ft.	Odor Emission Number	Odor Control Factor	Odor Emission Factor
Dairy	Freestall Barn	60000	6	1.0	36.0
Dairy	West Manure Storage	30000	13	1.0	39.0
Dairy	East Manure Storage	30000	13	1.0	39.0
				1.0	0.0
				1.0	0.0
				1.0	0.0
				1.0	0.0
				1.0	0.0
				1.0	0.0
				1.0	0.0
	Total Odor Emission Factor =				114.0

Figure 8. Example for a long-narrow facility including the entire system – 5% ODOR PRINT PAGE.

Site: **Long-Narrow Example Entire System**

Total Odor Emission Factor = 114



Stability Class		Distance Miles	Feet
F<3	=	1.34	7,087
F<7	=	0.81	4,251
E<7	=	0.51	2,715
E<12	=	0.39	2,035
D<12	=	0.28	1,460
D<18	=	0.20	1,036

The distances represented on this odor print are approximate distances that one must be away from the odor source to detect a noticable odor or stronger up to 5% of the time for each of the 16 wind directions.